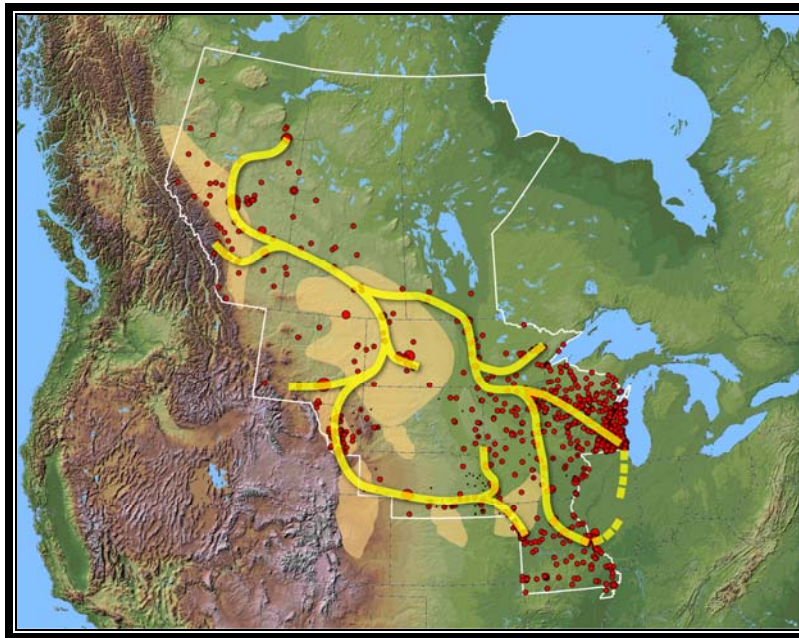


### E. Scenario 3

As Scenario 1C begins to demonstrate, the economies of scale for CO<sub>2</sub> transport could be significant. In a fully implemented GHG regulatory scheme, it would be conceivable that the majority of large industrial facilities (epitomized by large electric generation facilities) would be capturing CO<sub>2</sub>. The EERC's vision for a major pipeline system serving the PCOR region is laid out in Figure 6. As the map shows, the concentration of industry on the Iron Range makes it a likely route for a major artery of the CO<sub>2</sub> network.

**Figure 6. EERC's Vision of CCS in a Carbon Managed Economy**



Source: EERC

## VII. Preliminary Economic Analysis

Excelsior used the Mesaba Energy Project's proprietary financial model to identify the breakeven value of CO<sub>2</sub> (in 2006\$ per ton) captured in the 30% approach for each scenario identified in Section VI. This modeling is preliminary in nature and is intended to i) illustrate economic dependencies around important CCS Plan variables rather than absolute costs and ii) determine whether a more thorough investigation is justified. All cases assumed that capital outlays associated with CCS occur in 2011, and that CO<sub>2</sub> capture commences in the third quarter of 2014 and continues for 22 years (through the duration of the financial model).

The financing structure and economic assumptions used in the modeling of these carbon capture scenarios are consistent with Excelsior's assumptions in its current financial model used to evaluate the Mesaba Energy Project. The cases are modeled to recover the costs associated with the CCS program and maintain the required return to the projects equity investors. The effects of the sensitivities shown below are displayed as changes in NPV from a base case and are calculated using an 8% discount rate. Estimates for the cost of 90% removal are not available, so

only 30% capture was modeled.

Fluor developed an estimate for the cost of the 30% capture configuration,<sup>17</sup> and Excelsior integrated that estimate into the Mesaba Energy Project's financial model. There are two main economic impacts associated with carbon capture: equipment capital cost and reduced plant capacity, which also causes an increase in plant heat rate. The equipment includes the amine stripper and the CO<sub>2</sub> drier and compressor. Plant capacity is reduced and heat rate is increased because these processes are steam driven, and because the CO<sub>2</sub> would need to be replaced by steam as a diluent for NO<sub>x</sub> control. In an attempt to determine if CCS can be accomplished without additional costs to utility ratepayers, the cost of fuel increase on a megawatt-hour (MWh) basis corresponding to the heat rate increase was attributed and charged to the CCS project in the model assumptions. Total capital cost additions are currently estimated to be [BEGIN TRADE SECRET: END TRADE SECRET] and the anticipated increased O&M costs for that equipment is [BEGIN TRADE SECRET: END TRADE SECRET]. The capacity reduction for the IGCC Power Station is currently estimated to be [BEGIN TRADE SECRET: END TRADE SECRET], with the increased heat rate expected to be [BEGIN TRADE SECRET: END TRADE SECRET].

As for pipeline cost estimates, the Dakota Gasification Project's ("DGP") CO<sub>2</sub> pipeline to the Weyburn oil field was used as the basis for estimating costs. The DGP pipeline was built for \$120 million in 1997, and consisted of 204 miles of nominal 12" and 14" Schedule 40 pipeline.<sup>18</sup> Conservatively assuming it was all 12" pipeline and escalated to 2005 dollars, the total cost for a CO<sub>2</sub> pipeline in the Northern Plains is assumed to be \$60,920 per inch-mile. Based on the design capacity of the Weyburn pipeline, a nominal 12" Schedule 40 pipeline is sufficient to transport CO<sub>2</sub> produced by 30% capture at Mesaba One, with the Mesaba One and Two units requiring a 14" pipeline. A further conservative assumption utilized in the analysis is that the total pipeline network is built up front. Costs could be reduced by deferring network expansions to additional oil fields

Excelsior Energy modeled Scenarios 1A, 1B, and 2, and the results are presented in Table 2. For Scenarios 1A and 1B, revenues could be earned from both EOR and carbon credits sales (or through other carbon reduction benefits to ratepayers when constraints are imposed). This data illustrates that the economies of scale are important for CCS – the required price per ton drops significantly with larger volumes of CCS, despite the fact that 80 additional miles and an increased diameter for the pipeline would be necessary. Scenario 2 demonstrates that the Mesaba Energy Project could capture and sequester carbon at an even lower overall cost, although such capture could not reap EOR revenues. As explained above, these cost estimates are illustrative rather than predictive, and conclusions should be limited accordingly. The accuracy of these estimates must be refined by additional study before the economic viability of the project can be judged.

---

<sup>17</sup> Fluor Enterprises, Inc., *Mesaba Energy Project Partial Carbon Dioxide Capture Case*, October 2006, attached as Exhibit DC \_\_ (DC-7) to the Oct. 10, 2006 testimony of Douglas H. Cortez, OAH Docket No. 12-2500-17260-2, MPUC Docket No. E-6472/M-05-1993.

<sup>18</sup> See p. 857 of Kovscek, A. R. *Screening Criteria for CO<sub>2</sub> Storage in Reservoirs*, Petroleum Science and Technology, 2002. Vol. 20, No. 7&8, pp. 841-866. Also, see Dakota Gasification Company, *available at* [http://www.dakotagas.com/SafetyHealth/Pipeline\\_Information.html](http://www.dakotagas.com/SafetyHealth/Pipeline_Information.html).

**Table 2. Cost of Captured CO<sub>2</sub>**

	EOR	Pipeline length	Total CCS Cost (\$/ton)
Scenario 1A	Yes	445 miles	\$40
Scenario 1B	Yes	525 miles	\$35
Scenario 2	No	265 miles	\$32

Due to the high degree of uncertainty in many of the important assumptions, Excelsior conducted a sensitivity analysis. Scenario 1A was used as the base case for this analysis, and the results are shown in Table 3. Pipeline costs represent the greatest source of uncertainty, both in terms of the uncertainty of the cost assumed and impact that assumption has on total project cost. It is crucial that the range of this cost be narrowed, and the engineering studies proposed in Section I would address these and other issues. While the effect of capacity loss is nearly as material to the analysis, there is greater modeling certainty in the assumed values.

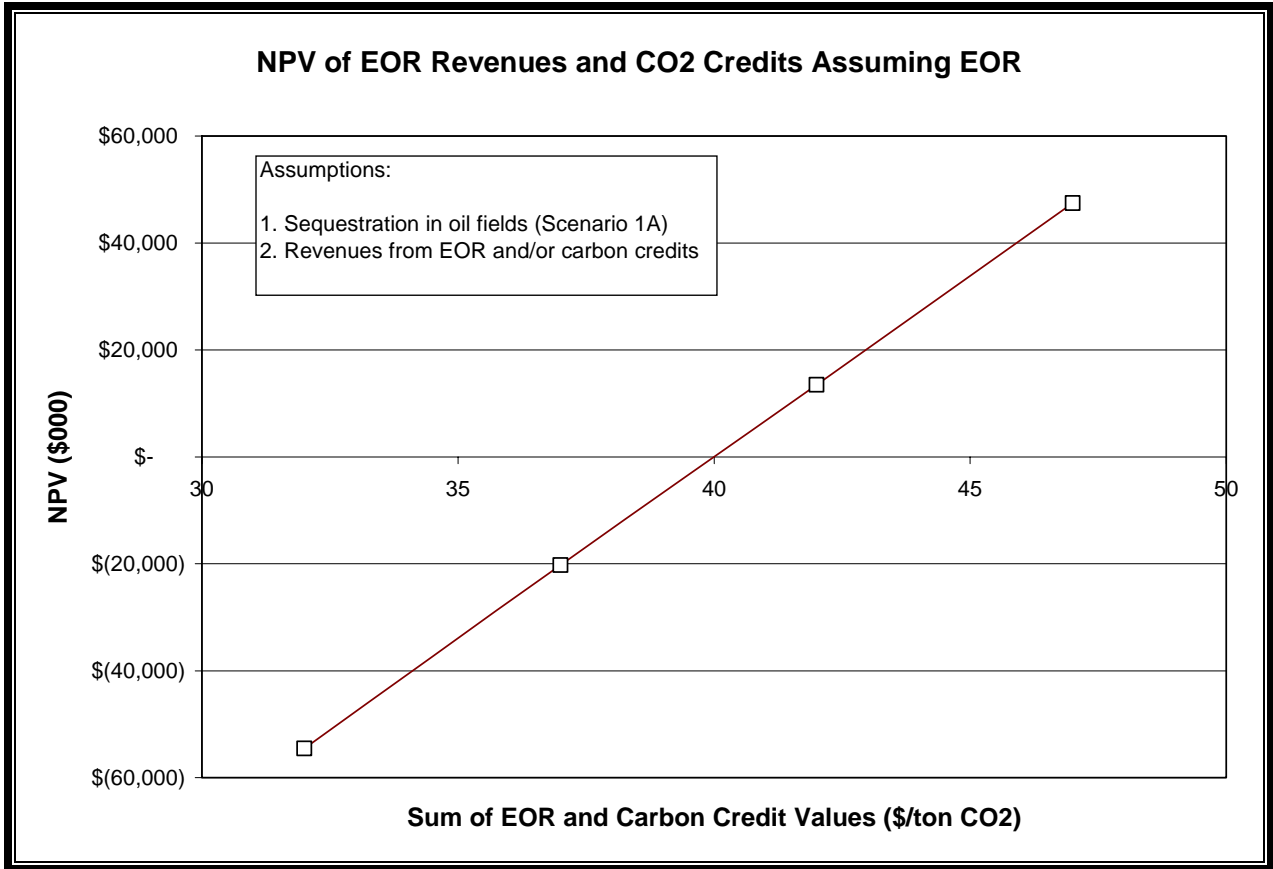
**Table 3. Sensitivity Analysis of CCS Costs**

<b>Factor</b>	<b>Case</b>	<b>Input Value Assumed</b>	<b>Required CO2 Value/Total CCS Cost</b>
<b>Pipeline Cost</b>	Low	\$30,145/in-mi	\$30/ton CO <sub>2</sub>
	Base	\$60,290/in-mi	\$40/ton CO <sub>2</sub>
	High	\$90,435/in-mi	\$50/ton CO <sub>2</sub>
<b>Plant Capital</b>	Low	[BEGIN TRADE SECRET:	END TRADE SECRET]
	Base	[BEGIN TRADE SECRET:	END TRADE SECRET]
	High	[BEGIN TRADE SECRET:	END TRADE SECRET]
<b>Capacity/ Heat Rate</b>	Low	[BEGIN TRADE SECRET:	END TRADE SECRET]
	Base	[BEGIN TRADE SECRET:	END TRADE SECRET]
	High	[BEGIN TRADE SECRET:	END TRADE SECRET]
<b>Plant O&amp;M</b>	Low	[BEGIN TRADE SECRET:	END TRADE SECRET]
	Base	[BEGIN TRADE SECRET:	END TRADE SECRET]
	High	[BEGIN TRADE SECRET:	END TRADE SECRET]
<b>Pipeline O&amp;M</b>	Low	\$890/mi-yr	\$40/ton CO <sub>2</sub>
	Base	\$1,780/mi-yr	\$40/ton CO <sub>2</sub>
	High	\$2,760/mi-yr	\$41/ton CO <sub>2</sub>

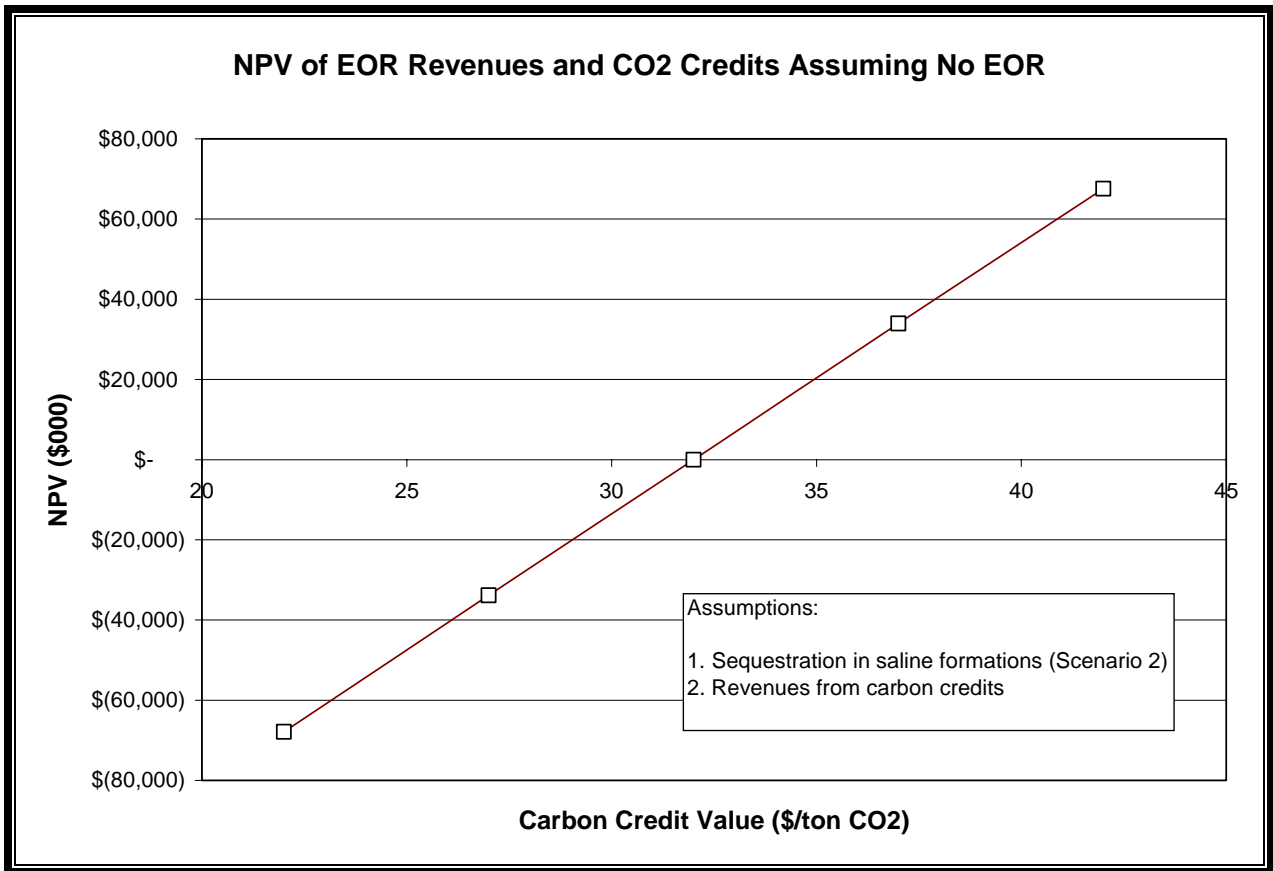
It is important to note that the greatest uncertainty surrounding the economics of a CCS project is revenue, as EOR depends upon volatile oil prices and carbon credit prices (or other economic benefits from reductions under carbon constraints) depend upon future regulation. However, such uncertainties are not specific to the Mesaba Energy Project and must be overcome by any major undertaking of CCS. The figures presented in the remainder of this section elaborate upon the modeled impact of CO<sub>2</sub> prices on the net present value of different scenarios in the CCS Plan.

Figure 7 shows the impact that the value of CO<sub>2</sub> has on project economics. This value for CO<sub>2</sub> is derived from either EOR or a combination of EOR and carbon credits or other CCS regulatory benefits, and corresponds to Scenario 1A with the baseline assumptions described above. Similarly, Figure 8 examines this impact if revenues are from carbon credits exclusively (that is, no EOR). CO<sub>2</sub> would be sequestered in saline formations, corresponding to Scenario 2. Thus, for Figure 8 the impact to the NPV is based on Scenario 2's \$32/ton case as the \$0 NPV reference.

**Figure 7. Sensitivity to Changes in Total CO<sub>2</sub> Revenue (\$/ton CO<sub>2</sub>) in Scenario 1A**

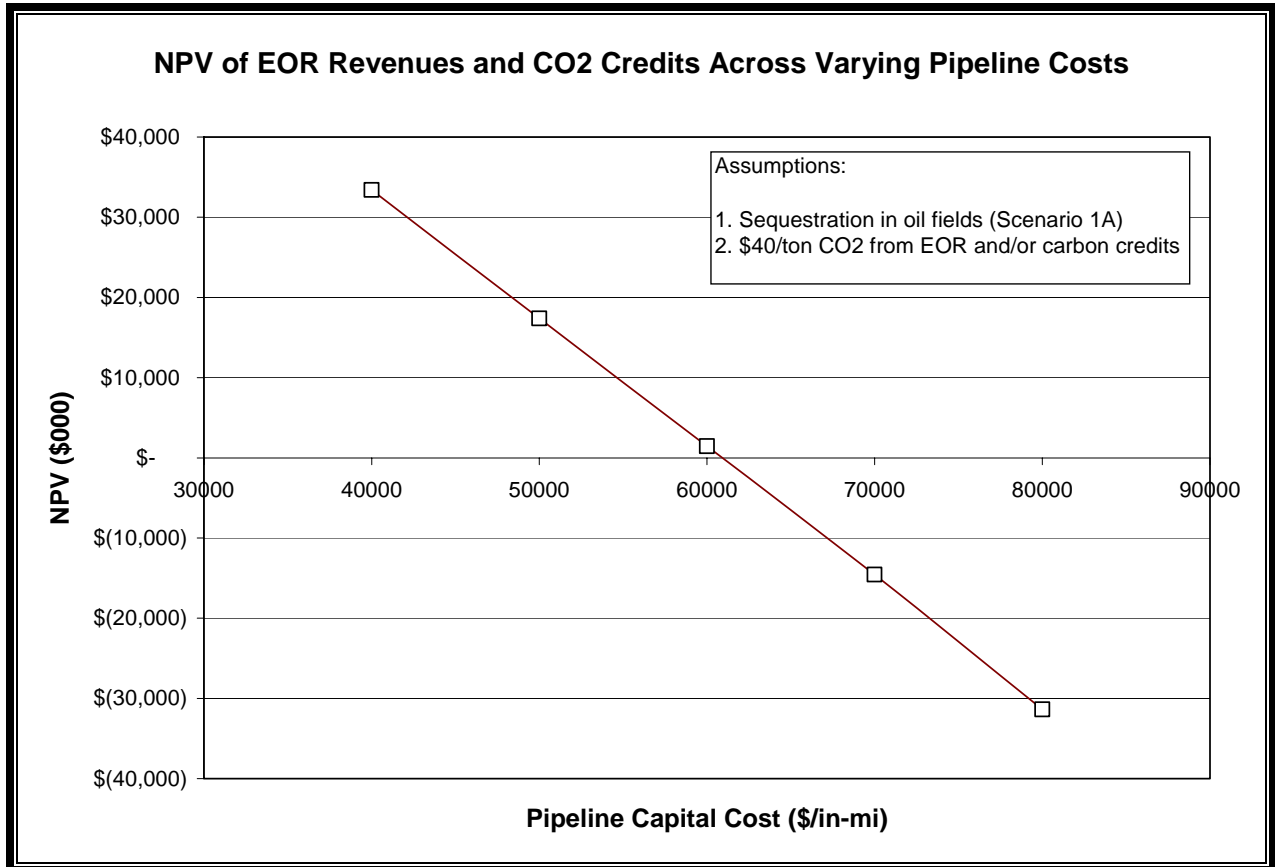


**Figure 8. Sensitivity to Changes in Carbon Credit Revenue (\$/ton CO<sub>2</sub>) in Scenario 2**



Changes in the NPV of different scenarios in the CCS Plan due to changes in pipeline costs are shown in Figure 9. This figure assumes that the total value of CO<sub>2</sub> will average \$40/ton.

**Figure 9. Sensitivity to Changes in Pipeline Costs (\$/in-mi) in Scenario 1A**



Carbon credits are currently trading at approximately \$17/ton in Europe.<sup>19</sup> The value of CO<sub>2</sub> for EOR is highly variable according to oil prices, specific field geology, and source competition. At oil prices of \$15–20/bbl, CO<sub>2</sub> can be worth \$10–16/ton for EOR, and more at higher prices of oil.<sup>20</sup> As carbon regulations are introduced and become stricter, and as the price of oil increases, the price of CO<sub>2</sub> can be expected to rise. Although it is premature to conclude whether CCS in any scenario presented here is economical, Excelsior believes that additional study towards that end is warranted.

The alternative sources of CO<sub>2</sub> for EOR in the fields identified in Scenario 1 are limited. The largest of these by far are conventional coal plants in the region, but post-combustion CO<sub>2</sub> capture for such sources has only been demonstrated at pilot scale. The cost per ton is expected to be higher for conventional coal than for the Mesaba Energy Project, even if a much shorter pipeline is assumed for the former.<sup>21</sup> Ethanol plants and natural gas processing facilities are able

<sup>19</sup> The market closing price on October 18 was €12.90 (<http://www.pointcarbon.com>), which is equivalent to \$16.25 USD.

<sup>20</sup> Intergovernmental Panel on Climate Change, IPCC Special Report: Carbon Dioxide Capture and Storage, p. 33 (2005), available at [http://arch.rivm.nl/env/int/ipcc/pages\\_media/SRCCS-final/ccsspm.pdf](http://arch.rivm.nl/env/int/ipcc/pages_media/SRCCS-final/ccsspm.pdf).

<sup>21</sup> See Ref. 2.

to produce CO<sub>2</sub> at a much lower cost than conventional coal plants, but lack the capacity to saturate the EOR market. Fields along the pipeline built by the Dakota Gasification Project can accommodate its supply for decades to come. Therefore, it is reasonable to expect that EOR revenues could be available to the Mesaba Energy Project across the time frames proposed.

Excelsior assumes that it will be positioned to obtain partial DOE cost sharing for construction of the CO<sub>2</sub> pipeline. However, irrespective of such funding potential, Excelsior believes it is in the interests of the both the Mesaba Project and the state to better understand the economic drivers for CCS programs and the need to firm up equipment/construction costs at the plant, along the pipeline route, and at the oil fields. Detailed engineering studies conducted under carefully defined scopes of work will help refine such costs.

The EERC, in conjunction with Excelsior, will develop CO<sub>2</sub> management options for the Mesaba Energy Project based on evaluations of sequestration opportunities associated with regional geologic formations/features and nearby terrestrial features. The study will match carbon sinks to the Mesaba Project and rank the sinks according to engineering, economic, and public-acceptance considerations. The schedule calls for the EERC to complete an analysis of the identified CO<sub>2</sub> management options in December 2006. Excelsior will use the results of this analysis to narrow the scope of its Phase III proposal to the DOE for demonstrating the commercial readiness of carbon sequestration via IGCC.

In preparing the Phase III proposal, the EERC and Excelsior will formulate best practices required to accomplish sequestration of CO<sub>2</sub> from IGCC facilities and publish the results as part of a manual that can be used by others undertaking IGCC projects.

## **VIII. Summary and Conclusions**

Excelsior has prepared this CCS Plan to offer the Commission and Minnesota ratepayers options to capture and sequester a significant portion of the CO<sub>2</sub> emissions from the Mesaba Energy Project. Based on the scientific and technical considerations, marketplace and operating assumptions, the financial analyses, and future carbon regulations assumed in this CCS Plan, Excelsior anticipates that future technical studies will verify that it will be feasible to capture and sequester CO<sub>2</sub> emissions from the Mesaba Energy Project. As explained in the CCS Plan, the most promising CCS scenario is for Excelsior to transport its CO<sub>2</sub> via high-pressure pipelines to the depleted oil fields associated in the Williston Basin located in North Dakota, southwestern Manitoba, and southeastern Saskatchewan.

This CCS Plan reflects the work undertaken to date by Excelsior and the PCOR initiative. Significant work remains to refine the engineering and economic information it contains. This work will be advanced by the PCOR initiative. Excelsior will continue to update this information as its work with PCOR progresses. Excelsior would be amenable to exploring a commitment with the Commission to apply the final \$2 million of its RDF award to further efforts to refine this plan. If feasible from the Commission's perspective, Excelsior would propose to accelerate the funding of that amount in order to facilitate a more rapid completion of a detailed engineering plan and cost proposal for CCS. Excelsior anticipates that such a detailed plan could be developed within a year from the date such funding is made available. The CCS Plan could also serve as the foundation for a competitive proposal in response to the Department

of Energy’s (“DOE”) planned Phase III solicitation for demonstrating full scale CCS projects. Accelerating development of a very detailed plan would enhance Minnesota and the Mesaba Project’s prospects to obtain federal matching funds under DOE programs.

It is in the long-term interests of the state to proceed expeditiously with the development of feasible CCS options. Excelsior looks forward to working with regulators, stakeholders, and industry participants to provide the important hedge to Minnesota consumers offered by the timely development of carbon capture and sequestration.

THIS PAGE INTENTIONALLY LEFT BLANK

# APPENDIX A2

## DOE Analysis of Feasibility of Carbon Capture and Sequestration for the Mesaba Energy Project

INTENTIONALLY LEFT BLANK

APPENDIX A2  
DOE ANALYSIS OF FEASIBILITY OF CARBON CAPTURE AND  
SEQUESTRATION FOR THE MESABA ENERGY PROJECT

This section discusses carbon capture and sequestration (CCS) and examines why it is not commercially feasible for the proposed action. The discussion includes consideration of the technical and economic feasibility of CCS given current and expected state-of-the-art technologies, foreseeable developments, market forces, and the regulatory framework in relation to the expected in-service date of the project.

The Mesaba Energy Project was selected in 2004 under the Clean Coal Power Initiative (CCPI) Round 2 Funding Opportunity Announcement. CCS was not a requirement of the Round 2 announcement, was not proposed in Excelsior's application submitted in response to the announcement, nor is it included within the project as negotiated and awarded in the DOE Cooperative Agreement. CCS will be the focus of the future CCPI Round 3 Funding Opportunity Announcement.

DOE has parallel research programs aimed at reducing the cost of electricity associated with power production and proving the technical viability of CCS technology. Advancements in gasification, turbine, and CCS technology must converge to make CCS technically and economically feasible. Projects like Mesaba will advance the state-of-the-art in gasification technology thereby making CCS more likely to be deployed in the future.

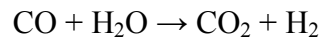
DOE expects that the combined efforts of these programs will enable large-scale plants to come on-line by 2020 that offer 90% carbon capture with 99% storage permanence at less than a 10% increase in the cost of energy services<sup>1</sup>. The planned in-service date for the Mesaba Energy Project is well in advance of the timeline for achieving the DOE goal.

#### Technical Feasibility of Carbon Capture

As discussed in Section 2.2.1.3, Section 5.1.2, and Appendix A1, Excelsior has presented a multiple-option carbon management plan to the Minnesota Public Utilities Commission (PUC). At its baseline, the Mesaba Energy Project would be designed with sufficient space available in its footprint for future installation of carbon capture equipment. Adjacent systems would also be designed to facilitate modification for interfacing the carbon capture equipment.

The plan includes the option of using commercially available amine scrubbers to remove carbon dioxide from the syngas stream prior to combustion in the gas turbines that would, assuming 100% subbituminous coal input, result in a nominal 30% reduction in overall carbon dioxide emissions from the plant. Incorporation of this base case carbon capture scenario would result in an adverse impact to plant efficiency and the price of electricity. Other commercially available capture technologies, such as Selexol<sup>®</sup> and Rectisol<sup>®</sup> would have a greater adverse impact on plant efficiency and the price of electricity<sup>2</sup>.

Excelsior's carbon management plan for the Mesaba Energy Project includes an additional option to convert the carbon monoxide present in the syngas to carbon dioxide for greater removal, if future conditions justified this option. This could conceivably result in about a 90% reduction in overall carbon dioxide emissions from the plant. However, the technologies required for this rely on a gas turbine that is capable of running on hydrogen-rich gas. For example, this process relies on converting water and carbon monoxide to carbon dioxide and hydrogen, as shown in the reaction below, using a water-gas shift reactor.



This results in a carbon monoxide-depleted, hydrogen-rich syngas. Conventional, commercially available combustion gas turbines envisioned for this project cannot operate on carbon monoxide-depleted syngas where the hydrogen concentration approaches 100%. Currently commercially-available combustion gas turbines at sizes much smaller than those envisioned for this project operate on hydrogen-rich fuels. These machines are typically operating on a blend of hydrogen (typically less than 60% hydrogen) and some other energy containing fuel, such as carbon monoxide or methane. However, the size, combustion technology and vintage of these smaller and older machines results in poor performance in terms of low efficiency and high emissions. This current experience, on smaller machines fueled with a hydrogen blend, does not translate to technology for larger machines fueled with nearly 100% hydrogen that would be needed for the Mesaba project, where high efficiency and low emissions are a requirement.

Currently, advanced turbines are in development that address these issues but are not expected to be commercially available at the Mesaba project's in-service date. Even when these advanced turbines are commercially available, the option of precombustion decarbonization to produce a hydrogen fuel would result in substantial capital cost, reduce overall plant efficiency and adversely impact the price of electricity from the Mesaba project. Testimony sponsored by Excelsior in the PUC docket estimated that under the 90% removal scenario, capital equipment cost could increase by up to 40%; corresponding increases in the net plant heat rate would approach 21%<sup>3</sup>. Other independent estimates are that the addition of 90% capture technologies to a gasification plant would increase the cost of energy by about 17%<sup>4</sup> and decrease the net power plant efficiency by about 6-9%<sup>5</sup>.

#### Technical Feasibility of Carbon Dioxide Transport

There are no sufficiently characterized geologic reservoirs capable of sequestering carbon dioxide within the state of Minnesota. The nearest geologic formation of potential interest would be the Lower Cretaceous saline formation approximately 265 miles from the proposed West Range Site. The nearest formation with the potential for revenues would be associated with enhanced oil recovery (EOR) in the Williston Basin of North Dakota. Both scenarios would require a pressurized pipeline; such a pipeline would need

to extend at least 400 miles to reach the Williston Basin. Much experience has been gained in the design, construction and operation of pipelines for transport of carbon dioxide for EOR. There are about 3,000 miles of existing carbon dioxide pipeline in the United States, including examples of pipelines up to 500 miles in length. It is therefore technically feasible to build a pipeline to oil fields or other sequestration sites within about 500 miles from the Mesaba Energy Project location. However, assuming rights-of-way, permits and off-take agreements could be obtained, the cost associated with the transport would significantly increase the cost of electricity.

### Technical Feasibility of Carbon Sequestration

Sequestration options include suitable EOR and injection into compatible geologic formations. Beneficial reuse, such as carbonation for soda pop, does not constitute sequestration because it ultimately results in release to the atmosphere. Sequestration is the subject of a great deal of research relative to the efficacy of long-term storage (i.e., permanence) and characterizing suitable “carbon sinks” to ensure that any potential adverse environmental impacts are understood and minimized. DOE has created a network of seven Regional Carbon Sequestration Partnerships to develop the technology, infrastructure, and regulatory framework necessary to implement carbon sequestration in different regions of the Nation. Planning for large-scale sequestration tests is scheduled to begin in fiscal year (FY) 2008 and the tests would run through FY 2017. The purpose of the tests is to demonstrate that large quantities (e.g. one million tons of carbon dioxide per year) can be transported, injected, and stored safely, permanently, and economically.<sup>1</sup>

Large-scale and long-term commercial application of carbon dioxide injection for EOR has occurred in the Texas Permian Basin and in the Weyburn field of the Williston Basin. However, these are economically-driven operations to increase oil production not necessarily scientifically-driven to prove the technical feasibility of permanently sequestering carbon.

Therefore, the technical feasibility of carbon sequestration for the Mesaba Energy Project cannot be validated in the near-term until extensive field tests are conducted to fully characterize potential storage sites and the long-term storage of sequestered carbon has been demonstrated and verified. Further, an MIT study<sup>4</sup> concluded that the major uncertainties surrounding geologic sequestration should be resolved within 10-15 years, which is consistent with the DOE Carbon Sequestration Program goal.

### Economic Feasibility of Carbon Capture and Sequestration

The effect of CCS on the cost of electricity from the Mesaba Energy Project has not been quantified. However, there have been a number of studies of the costs of CCS for IGCC plants that show the costs of CCS could increase the cost of electricity by as much as 40%,<sup>6</sup> depending on assumptions regarding the value of the carbon dioxide produced. No statutory or regulatory requirement exists for CCS. Nor does a viable market currently exist for carbon credits. Environmental and construction permitting associated with transport and sequestration would significantly delay the project, further increasing the

cost of electricity. Even if the carbon dioxide could be sold for EOR operations, the revenues from carbon dioxide (estimated at about \$20 per ton) would be grossly insufficient to recover such costs. Hence, imposition of CCS on the project will effectively make the cost of electricity non-competitive.

### Summary Conclusion

Carbon capture and sequestration is not considered feasible for the Mesaba Energy Project at this time. However, the carbon management plan for the Mesaba Energy Project is a logical starting point from which the PUC can derive findings and thereby establish the appropriate timing and price at which carbon capture and sequestration becomes in the Minnesota ratepayers' interest. Without an order from the PUC that incorporates the costs associated with CCS within the power purchase agreement, the Mesaba Energy Project would not be economically viable.

### References

1. Carbon Sequestration Technology Roadmap and Program Plan, 2007, NETL.
2. Comparative IGCC Performance and Costs for Domestic Coals, Conoco-Phillips, Gasification Technology Council, May 2005.
3. Prepared Rebuttal Testimony of Douglas H. Cortez on behalf of Excelsior Energy Inc. and MEP-I LLC, October 10, 2006, page 9.
4. The Future of Coal in a Greenhouse Gas Constrained World, MIT, [http://sequestration.mit.edu/pdf/GHGT8\\_Herzog\\_Katzer.pdf](http://sequestration.mit.edu/pdf/GHGT8_Herzog_Katzer.pdf)
5. DOE/NETL 401/053106
6. Cost and Performance Baseline for Fossil Energy Plants, DOE/NETL-2007/1281, May 2007.